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# Cutaneous and kinaesthetic space.

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# CUTANEOUS AND KINAESTHETIC SPACE[1]

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## 1. *Perception of form and size*

Zigler and Northup (40) find that tactual form, produced by a cardboard form applied to the forearm with vision excluded, is not as definitely apprehended as tactual pressure. The latter is invariably perceived, while the tactual form is not definitely given in a considerable percentages of cases, and is not apprehended at all in some instances. Form discrimination is minimal in cases of pressure totally devoid of outline and maximal where the complete contour of a figure-form is given at all points in terms of the tactual impression. Geometrical figures must have a main dimension of 12 to 15 mm. to give rise to definite tactual form impressions on the middle of the forearm. The optimal main dimension for the mid-forearm, by the author's method of stimulation, is 20 mm. In another study Zigler and Barrett (41) applied figures (square, hexagon, diamond, equilateral and right-angle triangles) with a pressure of 500 gms. on the palm, ball of the thumb, and volar surface of the forearm. Three forms of figure (solid, outlined, and pointed) cut out of rubber were used. The clearest discriminations were obtained from outlined, solid, and pointed figures in the order named. The main supplementary cues for the perception of point figures are "tactual tied-imagery" and "visual imagery." The most adequate perceptions are furnished by the thumb, palm, and forearm in the order given. Acute angle forms were perceived more frequently than obtuse or right angle ones. The following stages may be distinguished during the gradual rise of perception: (a) A stage of shapeless pressure, (b) an intermediate stage in which one or two salient features of the form acquire definiteness of clearness, and (c) the final stage in which the outline is clearly and completely given. DeGowin and Dimmick (6) performed an experiment in order to obtain "descriptions of the spatial patterns of several touch perceptions whose stimuli have definite visual patterns and to determine

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[1] This paper includes the literature on Cutaneous and Kinaesthetic Space appearing during the last four years.

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whether, as in the case of vision, tied images play any part in these images." The forms used were a line, circle, equilateral triangle, and square. The results show that purely tactual perceptions do not naturally take on the meaning of form that correspond with our visual geometrical forms. When such tactual patterns of form are built up, it is only by the addition of other elements, usually visual. In spite of their lack of resemblance to the visual forms of the stimuli the tactual patterns are stable and readily recognized. Tied images similar to those in vision and audition, play a large part under the right conditions in filling out the tactual patterns from incomplete stimuli. Rosenbloom (29) sought to determine whether or not the principles, found by the *Gestalt* school to govern visual perceptions, are equally applicable to tactual perceptions. Seven figures (circles, squares, triangles), 3 complete and 4 incomplete, were applied to the palm of the hand. After stimulation the O's were asked to draw or describe the figures and to indicate the degree of certainty of their response. It was concluded that: (a) closed figures are more easily perceived than open ones; (b) the circle and the triangle have the best figure qualities of the seven figures used; (c) the open figures tend to be perceived as closed; and (d) the figure has properties of its own and influences its component parts. Ueno (33) reports experiments on perceptual judgment of space bisection. He worked with school children, soldiers, college students, adults, and blind people. Bisection, lines, a pair of dots, angles, and a glass rod were presented vertically as well as horizontally. The lines were drawn on white cards, 2 mm. wide and 20, 40, 60, 80, and 100 mm. long. The dots were .5 mm. in diameter, and the pairs were separated by distances of 20, 40, 60, 80, 100 mm. The angles were made by two lines .2 mm. wide and 68 mm. long. Angles of 30, 45, 60, and 90 degrees were used. The glass rod was 8 mm. in diameter and 550 mm. long. A band was fixed at each end and a third band in the center could be slid along the rod at will. Each subject gave ten judgments on the perception of each of these stimuli. The average of these judgments was the individual score from which the mean constant and the variable errors of a group was computed. The following results were obtained: There were great individual differences in regard to age and sex. The variable errors did not change much with reference to the intensity of the stimulus. The right halves of lines and dots in horizontal positions and the upper halves of lines and dots in vertical positions showed a constant error of overestimation. When the vertex of the angle was above, the left halves were overestimated; when the vertex was on the left, the lower halves were similarly judged. The bisection of the glass rod by means of muscular and tactile cues verified Weber's law. There were no important differences between blind and seeing subjects. The constant and variable errors could be decreased by practice, but the direction of constant errors tended to remain stable. Warden and Flynn (36) found that the apparent size of a series of colored cartons placed side by side does not depend upon the intrinsic quality or upon the immediate contrast effect of their color, but upon their specific serial arrangement. The color-weight illusion was found to be greater than the color-size illusion.

### 2. *Perception of length and distance*

Using a solid pasteboard plate of constant width but varying in length from 4 to 20 mm. (4, 8, 12, 16, and 20), Faucault (8) studied the perception of length on the three phalanges of the index finger. Immediately after noting the length of the stimulus the subjects were required to indicate on a standard scale the varying lengths which seemed to them to approximate most closely the tactual experience. It was found that the per cent of error decreased as the distances were increased. The diminution of error was rapid at first, then slow with a tendency to remain constant. In comparison, the second phalange yielded fewer errors of discrimination than the first and the third. Similar experiments were carried out on the dorsal and palmar sides of the finger. These showed a diminution of errors in passing from the dorsal to the palmar side. The greater accuracy of the second phalanx and of the palmar side of the skin is attributed to the greater density of sense organs in these regions. Some individuals increased their ability to discriminate by movement of the stimulus while others did not. On the basis of these experiments and certain theoretical considerations the author concludes that the perception of length on the skin "comprises a fusion or assimilation, with the ensemble of sensations, of an image which recapitulates past perceptions." This results in individual differences of ability to discriminate length by means of the skin. Kuroda (20) reports a study of distance perception in a two-year-old child. The child was placed before a table, 90 cm. long, 70 cm. wide, 41 cm. high, and made to get candy placed at various points around the edge of the top. Under these conditions the child chose the shorter route 10 times out of 12 trials. In order to determine to what extent orientation played a part in the discrimination, a desk was placed at one of the shortest sides of the table thereby extending the circuit 136 cm. Under these conditions the child chose the longer route three times and the shorter route twice. Next a box was added to the farther end of the annexed desk extending the circuit 84 cm. Under these conditions the child chose the shorter route 3 times and longer route once. The ambiguous results under the first and last conditions show that orientation is not an indispensable factor in the child's discrimination of distance. Kiesow (17) used the method of minimal changes to make comparisons of linear distance. In 1,400 trials with one subject, lines differing in length were compared. Weber's law was found to hold under conditions outlined in the article.

### 3. *Perception of movement and speed*

Michotte and Galli (23) measured the discriminatory threshold for the change of position in passive movements of the subject's arms. The apparatus consisted of two handles which moved along the side of the ruler and could be stopped at any position by the experimenter. The subject who was blindfolded kept his hands on the handles and judged the displacements undergone. From these experiments the authors deduce the theory that space may be phenomenally present in a kinaesthetic form. This is in opposition to current conceptions that the space between the two hands does not correspond to a sensitive surface, and that only the points which limit this space can be perceived. The authors find a strong analogy between visual and kinaesthetic perception of space. Hulin (14) experiments on the illusion of apparent movement on the skin of the forearm with a modified Benussi kinohapt. From seven subjects 13,500 judgments were obtained on the effect of two tactual stimuli presented at temporal intervals ranging from simultaneity to 300$\sigma$ and spatial intervals varying from 5 to 150 mm. with a duration of 150$\sigma$ and a weight of 4 gm. Of the judgments taken, 29.7 per cent represented experiences of some sort of apparent movement in the tactual field. The optimal time relationship between the two stimuli was 75$\sigma$. The various spatial separations were found to give the appearance of movement with uniform frequency. The perceptual complex was shown to involve four variable factors, perseveration, pressure irradiation, visual imagery, and kinaesthesis. Pellegrini and Ponzo (27) report interesting studies on judging the speed of an automobile in motion. The speed was judged by the subject while sitting in the back seat of an automobile. The judgments of errors are less during constant motion than while slowing down or speeding up. Speeding up results in overestimation whereas slowing down results in underestimation of speed. Another study on the perception of changes of speed while riding in an automobile is reported by Kunze (19). The 34 subjects serving in this experiment were also tested in nine performances believed to be components of the general practical speed judgments, acoustical, optical, and vibrational components, reaction time, skill, etc. Only the auditory test results (judgment of changes in sounds) correlated significantly with the practical speed judgments.

### 4. *Perception of load*

Weber (37) discovers that the kinaesthetic perception of intervals of space and time may be altered by the presence of " fields of force " or load. A given distance under load is phenomenally equivalent to a smaller time interval under less load. There are indications that load equally affects the perception of area and the phenomenally straight line, consequently perhaps also the degree of angle. In another experiment Weber and Dallenbach (38) sought to obtain a more complete " geometry " of the " muscle sense." The effect of load on judgment of area, angle, and arc was studied by the method of constant stimulus-differences. Stimulus-area of 5 different sizes were used, the middle one of which served in every case as the standard. The perimeter of the square area was traced by the blindfolded subject with a stylus which could be weighted in three different amounts. Twenty-five comparisons were made of the standard and of every variable by every subject under each of the 6 experimental conditions. The changes which were produced in the limens by the changes in the size of the outline traced led to the following generalizations: "(1) A given area sensed under load appears to be phenomenally enlarged. (2) A given angle traversed under load appears to be phenomenally more acute, *i.e.,* smaller. (3) A given arc traversed under load appears to be phenomenally more sharply curved, *i.e.,* to be a curve of smaller radius. (4) As a load is increased, critical points are reached where the results due to the load are reversed." These results are believed to suggest tentatively that the geometry of the muscle is hyperbolic.

### 5. *Perception of stimuli of different qualities*

Malamud (21), in an attempt to determine the tactual stimulus limens, applied to the volar surface of the arm two hard rubber points, followed by two sharp metallic points, and vice versa. From the thresholds obtained the author summarizes as follows: " (1) Two spatial contents objectively equal but limited by stimuli of different qualities are perceived as unequal; (2) that such contents between the pain-bearing stimuli are perceived as smaller than between tactile; (3) these qualities must be cutaneous in type, in other words, cutaneous sensations; for other qualities which are of geometrical value do not seem to exert such an influence."

### 6. *Localization of temperature*

In an introspective analysis of the experience of heat Burnett and Dallenbach (3) find that heat is variously localized. At times it appears "surfacy" and on the skin, at other times "voluminous" and in the arm. One observer localized it outside of the body. Strughold (32) finds that the threshold of cold is much lower in the sclera and the cornea, where the end-bulbs of Krause lie close to the surface, than elsewhere where the bulbs lie deeper. In a very careful survey of temperature-discrimination within the range not involving pain or extreme discomfort, with special reference to the validity of Weber's law, Culler (5) reports that at skin temperature the sensitivity of the left hand is more than twice as great as that for the right hand. Helmuth and Lueg (12) question the existence of simultaneous contrast in the field of temperature sensations. Temperature sensations are believed to be confined to the area which is directly stimulated.

### 7. *Localization of pressure, pain and tickle*

Kiesow (17) raises the question whether or not Weber's law holds if only a single tactile organ is stimulated. He finds that the law holds also under such conditions and that the attempt to explain the results on the basis of variations in intensity of the stimulus must be considered futile. Friedman (9) repeated some of Czermak's experiments on the two-point threshold to determine the spatial threshold in children. The work was done on 48 normal and 48 subnormal children, aged ten to fifteen years. A specially constructed apparatus (Spearman's aesthesiometer was found inadequate) was used for stimulation. In normal children the results showed a decrease in spatial sensitivity up to the age of twelve years, after which there was an increase. This increase is believed to be more dependent upon intellectual than upon anatomico-physiological factors. In abnormal children there was a tendency for spatial sensitivity to increase with mental age.

Mayer (22) used both Weber's and Volkmann's method of localizing pain and pressure on an area of 50 cm.$^2$ on the volar surface of the left lower arm. A correct localization was more easily achieved after pressure than after pain. In 1911, Ponzo had found just the opposite. von Skramlik (34), in a theoretical paper, agrees with Mayer who did her work under his direction. Kiesow (16) repeated Goldscheider's experiment on the cornea and conjunctiva bulbi in order to settle a difference of opinion as to the arousal of a pure sensation of cutaneous pain. The experiments were performed with small stimulus rods about 6 cm. long. On the point-end of the rod was twisted a little flake of sterilized cotton that ran out into a fine point. The author's results favor von Frey's theory, and lead to the conclusion that separate physiological mechanisms must be assumed for the sensation of pain and touch, and that the conditions of their arousal are different. Nafe (24) finds that the qualities of felt (cutaneous and kinaesthetic) experiences are analyzable patterns. Felt experiences are, qualitatively regarded, patterns of brightness (or sharpness) of greater or less complexity. These experiences may be localized. In another study on dermal sensitivity with special reference to qualities of tickle and itch, Nafe (25) finds no evidence for the existence of specific tickle and itch spots. The theory of double stimulation in the production of tickle is suggested.

### 8. *Clinical observations*

Holmes (13) finds that in cortical lesions those forms of sensation which give us information as to the position in space of parts of the body, the spatial relation of different parts of our limbs and of their movement, and the ability to recognize objects by handling them are more affected than cutaneous sensitivity. Lesions of the sensory area of one hemisphere result in disturbances of sensation which are always limited to the opposite side of the body and may extend over the whole of the side, or may be limited to a limb or a portion of a limb. Wilson (39) reports that " dysaesthesia " (including apparently spontaneous disturbances of sensations which patients describe as "burning," "coldness," "wetness," "numbness," "deadness," "tingling," "pricking," "sensation of something moving," etc.) sometimes has a neural origin, while under other conditions a vascular or sympathetic vascular origin underlies the awareness of these tactile, painful, and thermal dysaesthesias.

### 9. *Synaesthesis*

Dallenbach (4) reports a case of synaesthesis of "pressury" cold hitherto undescribed. The subject's cold spots were of two kinds, those that gave the usual experiences, and those that gave secondary experiences localized in and around the teeth and cheeks. These latter spots occurred upon all spots of the body which were investigated, though with varying frequency. The secondary experiences are described as light, transient, and pressury in quality and are always localized on the side of the body stimulated. In view of the fact that the observer has a synaesthetic inheritance this case is believed to lend evidence to the hereditary theory of synaesthesis.

### 10. *Illusions*

Sharp (30) describes a rather novel tactual-visual illusion. The individual brings his two hands before his eyes, palms facing him, with the index fingers touching end to end. Holding the hands in this position from 20 to 30 cm. in front of the eyes the subject fixates a more distant point in such a way that he sees both of the fingers and the point. By drawing the fingers slightly apart the subject experiences the weird illusion of seeing the first joint of either one of the fingers floating in the air. It no longer seems to have any connection with the rest of the body, either visually or tactually. Gatti (10) reports an illusion in the kinaesthetic-tactual field similar to Zöllner's optical illusion.

### 11. *Theoretical*

After reviewing the various theories of local signature, Peterson (28) states his own theory in terms of orientation tendencies. He enumerates the following advantages in "conceiving local signature merely as orientation tendency instead of some mysterious guidance of action by assumed sensory signs or as some sort of reference to location by these signs": (a) The problems of spatial orientation become subject to experimental investigation of an objective nature. (b) The question of consciousness has no relevancy and need not enter into the experimentation or interpretation of spatially discriminative behavior. (c) No other theory of local signs accounts for the changes in the sensory nerves affected by the stimulation and in the proprioceptive fibers involved in the relevant movements, on the one hand, and changes in the motor nerves connected with the relevant effectors, on the other. (d) Differences between the nativists and empiricists become at once resolvable.

(e) The interminable controversies as to whether sensations have extension inherent in themselves or whether space can be built up by association of non-extensible mind-stuff become useless and even ridiculous. (f) Local signature and perception become only special problems in the special field of learning and are subject to objective experimental investigation. Gemelli (11) points out that while the Gestalt psychologist, by his attack upon the atomistic concept of the structuralist, has given new life to the study of perception, his denial of the possibility of analyzing perception into its constituents is untenable. Gemelli believes that a functional analysis of perception is possible. Perception itself is for him the organization of elements of sensorial origin into a whole to which we attribute a meaning. In harmony with this theory he posits six laws of perception: The law of least effort; the relative functional autonomy of perceptual elements; the functional unification of all elements of perception; the definite character of perception; rectification of sensory data and constancy of the intuitive organism; and the finality of the intuitive organism and of the significance of the "objects" of perception. The author finds these theoretical considerations supported by experiments in his laboratory. Besides a visual and a tactual space von Uexkull and Roesen (35) discover an "active" space within which our movements occur. As measured by arm movement, the shortest discriminable distance in this active directional space is about 2 cm. in each direction. The extent of this distance is registered by the resistance of the antagonistic muscles. Active space is made of a tridimensional network (stellen), held in a sensible coordination system extending from right to left, forward and backward, etc., independent of the position of the head and fixed for the individual. The necessity for the agreement of the co-ordination of visual space and active space results in nystagmus. The movement-signs are not to be identified with muscle sensations, but are of central origin. Reasoning from a series of experiments involving careful introspective analysis of the failure of perception in the sentient surfaces, Bose (1) reaches a thesis that perception is an illusion due to the influence of "active attitudes." He posits a law of localization which suggests that the localizing capacity of any part of the skin varies inversely with its aesthesiometric index. Delaunay (7) gives an account of the genetic development of visual and combined visual and kinaesthetic perception in the child. Parsons (26) attempts to build up a whole system of space perception upon Head's classification of sensibility. He prefers, however, to substitute the term "dyscritic" for Head's protopathic sensibility. From a consideration of the comparative anatomy of vertebrates, he finds that the primitive apparatus of the tactile sense can be recognized from amphioxus to man. Stopford (31) discusses his clinical observations of sensation following section and suture of a peripheral nerve, and finds that the recovery of the cutaneous and deep sensation occurs in two stages. It is believed that two exactly comparable systems exist in both cutaneous and deep sensibility—one composed of elements of sensation concerned with protection, and the other with discrimination. It is not practicable to isolate the sensation of the skin from that of the deeper tissues. The existence of the two systems is explained by reference to the functions of the thalamus and the sensory cortex, together with a recognition of the disturbances of the intraneural patterns which are known to result from the operation of nerve suture. The central explanation accounts for all the observed facts for the normal sensibility of the glans penis and is also in accord with our knowledge of the evolution of the nervous system.

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# SYNESTHESIA

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Anschütz (1) has made a detailed study of the synesthetic experiences of three artists. The article contains many drawings in color and in black and white, which were made by the subjects, and which show the colors and shapes that accompany the subjects' medical experiences. The author discusses at some length his psychophysiological theory of synesthesia. As he does not believe that there can be any direct connection between auditory and visual paths or centers, he postulates a theory of inner vision (inneren Sehens). It is difficult to interpret this term without knowing the author's concept of mind, but the equally vague term "higher mental process" is probably a sufficiently close translation. At the end of the paper there is a suggestion that synesthetic images may be the explanation for the visions often seen in occult experiences.

Anschütz (2) has also made a thorough analysis of the colored hearing of a blind subject, which in subsequent articles he refers to as the case of Dörken. The first part of the paper is devoted to an investigation of the colors and hues reported by the subject. Data and curves are given regarding the brightness, saturation, hue, etc. In the second part are presented more objective records, such as the relation of absolute pitch to hue. He concludes that many laws of synesthetic vision are to the smallest detail identical with ordinary vision.

Mahling (8) has written a detailed historical and critical treatise upon the problem of chromesthesia. He has also presented a long bibliography in two parts, the first dealing with the specific problems of colored hearing, and the second with the more general problems of color and tone. The bibliography is arranged in both alphabetical and chronological order.

Argelander (3) has made an extensive experimental study of chromesthesia, with emphasis upon the exact control of the tones and colors. The subjects were instructed after hearing the tone to select the synesthetic color from a series of colors placed before them. The experimenter included under colored hearing not only cases where the observers imaged the color, but also where they were reminded of the color, but could describe it only with difficulty. As one would expect, the author found a certain lack of constancy and agreement. A number of problems were investigated, such as the relation of the tone to brightness, the reverse relation of a tone imaged to a seen color, the connection of colors with vowels, vowel pitch with brightness, vowel color with tone color, and colors with musical chords. A comparison was also given of the author's results with those of other investigators. Argelander undoubtedly did not know of Mahling's work, for a large part of the paper is devoted to a history of the problem and methods, and an account of the different theories of colored hearing, and the facts of visual sensations which might bear upon these theories. There is also a bibliography of 456 articles. As these two papers contain good histories of the problem and extensive bibliographies, they will be of great value to anyone experimenting in the field of synesthesia.

Wheeler and Cutsforth (10) have continued their investigations of the functioning of the synesthetic imagery of a blind subject. As in a previous paper, they have compared the results of the introspective report of the subject upon his method of concept building with those obtained by Fisher (*Psychol. Monog.* 21, 1916) upon normal subjects. Nonsense figures of clay were placed successively upon the observer's hand, and he reported upon the process of building a concept of these figures. The authors confirm their former results that synesthesia is not functionally an unusual process in the mental equipment of the subject, but is employed, as a rule, in both perception and conception. They again confirm Fisher's conclusion that meaning did not accrue to an imageless content but rather to imagery, at least in the case of this subject. As in a previous paper, they lay more stress on the kinesthetic factors in concept building than did Fisher.

Dallenbach (4) has described a case of a new form of synesthesia. The subject felt light, transient, pressure sensations in and around the teeth and cheeks when certain cold spots were stimulated. These "toothy" cold spots were located on all parts of the body on which experiments were performed. As the subject's mother also had a type of synesthesia, the author believes that the results support the theory of the inheritance of synesthesia.

Mayer-Gross (9) has sketched briefly some of the recent work on synesthesia, and then has described the synesthetic effect produced by mescal on normally nonsynesthetic subjects. The synesthesia was between audition, vision, and touch. Most of the secondary sensations were visual, though frequently touch sensations were aroused by visual and auditory stimulation. The author believes that these synesthetic phenomena under mescal will be helpful in explaining certain hallucinations in schizophrenic patients, and may also aid in determining the physiological processes underlying synesthesia.

W. Jaensch (7) has described his brother's, E. R. Jaensch's, classification of synesthesia in three classes: feeling, perceptual, and sensational synesthesia. He believes the quasi-visual experience of the "feeling-synesthetic" is similar to certain experiences of a hallucinatory character of the schizophrenic, and may explain the latter.

Hein (6) performed a series of experiments upon supposedly nonsynesthetic observes to determine if there was any consistency in the arrangement of colors in relation to tone. He later found that some of the observers were synesthetic. Notwithstanding the difficulty of evaluating the data, the author believes the results bear upon the problem of the development of color vision, and upon color nomenclature. According to the author, synesthesia seems also related to the problem of eidetic imagery. A mathematical treatment of the results revealed a law regarding the arrangement of the colors in relation to musical pitch. This arrangement seemed to throw light upon the inner relationship of the colors. The law seemed to hold only for nonsynesthetic and musically naïve synesthetic observers. The results of the musically gifted synesthetic observers follow another law.

Dauffenbach (5) has emphasized the importance of the relation of color to music. He has called attention to this relation in the music of famous composers, and has quoted a number of critics on the subject. He believes that it would be difficult to explain this relation on the basis of physics or physiology, and concludes that it is an association through the congruity of emotional responses. He does not refer directly to synesthesia in this article.

A number of articles have been written recently on the use of color in connection with music, but their review would take us beyond the scope of this report.

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